E949 Technical Note K-074

Analysis of the 2/3 E949 pnn2 data

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February 19, 2008

Abstract

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Background Component	Entire "Loose"	Cleanest cell "Tight"
$K_{\pi 2}$TT scatter	$0.575 \pm 0.184^{+0.063}_{-0.201}$	$0.115 \pm 0.058^{+0.039}_{-0.022}$
$K_{\pi 2}$RS scatter	-0.0070 ± 0.0042	-0.0031 ± 0.0018
$K_{\pi 2\gamma}$	$0.0500 \pm 0.0084 \pm 0.0030$	$0.0182 \pm 0.0047 \pm 0.0011$
K_{e4}	$0.176 \pm 0.102^{+0.233}_{-0.124}$	$0.034 \pm 0.034^{+0.142}_{-0.026}$
CEX	$0.092 \pm 0.053^{+0.070}_{-0.018}$	$0.0046 \pm 0.0046^{+0.0046}_{-0.0015}$
Muon	0.0281 ± 0.0281	0.00374 ± 0.00374
Two-beam	0.0438 ± 0.0200	0.00317 ± 0.00317
One-beam	0.00157 ± 0.00157	0.00035 ± 0.00035
Total Background	$0.966 \pm 0.220^{+0.309}_{-0.246}$	$0.179 \pm 0.068^{+0.152}_{-0.035}$
Total Acceptance	$(1.841 \pm 0.065^{+0.194}_{-0.194}) \times 10^{-3}$	$(0.600 \pm 0.176^{+0.063}_{-0.064}) \times 10^{-3}$
Single-event sensitivity	$(0.432 \pm 0.015^{+0.046}_{-0.046}) \times 10^{-9}$	$(1.325 \pm 0.389^{+0.141}_{-0.143}) \times 10^{-9}$

Table 1: The estimated backgrounds for the entire signal region, referred to as "loose" elsewhere in the text, and the cleanest cell, referred to as "tight", to be used in the analysis. The first error is the statistical uncertainty; the second error (when present) is the estimated systematic uncertainty. The systematic uncertainties for the K_{e4} and CEX backgrounds are assumed to be fully correlated. The cleanest cell corresponds to the tight settings of the KIN, TD, PV and DELCO cuts. The background due to $K_{\pi 2}$RS scatters is assumed to be negligible and not included in the totals. The bottom rows contains the total acceptance and single event sensitivity of the two regions. The acceptance given in the table does not include the additional factors of $f_S = 0.7740 \pm 0.0011$ and $\epsilon_{T\bullet 2} = 0.9505 \pm 0.0012 \pm 0.0143$.

1 Executive Summary

Expected backgrounds from the 1/3 and 2/3 analyses are given in Table 1 as well as the single event sensitivity and total acceptance. A number of small changes to the analysis have occurred since Technical Note K-073 [1] that described all the changes to the analysis with respect to the prior pnn2 analysis and the E949 pnn1 analysis. None of these changes had a profound effect on the conclusions from the 1/3 note.

This note is organized as follows. Section 2 summarizes the changes with respect to the 1/3 analysis note [1]. The $K_{\pi 2}$-scatter, $K_{\pi 2\gamma}$, beam, muon, charge exchange (CEX) and K_{e4} background estimates are given in Sections 3, 4, 5, 6, 7 and 8, respectively. Studies to ascertain the effect of contamination of background samples is presented in 9. Section 10 describes the acceptance measuremnts and Section 11 contains the description of the kaon exposure. The investigation of flaws and loopholes with a single-cut-failure study is described in Section 12. The sensitivity of the analysis is evaluated in Section 13.

2 Summary of changes with respect to the 1/3 analysis note

Several changes to the analysis were made subsequent to the 1/3 analysis note [1]. None of the changes had a significant effect on the background or acceptance estimates. The changes are

1. Fix to the CCDBADTIM cut. This cut requires consistency between the fitted first pulse and the global kaon time. Originally this cut was only placed on the first fitted pulse for fibers with double-pulse fits only. While searching by visual scan for evidence of K_{e4} contamination in the $K_{\pi 2}$ target-scatter 1/3 normalization branch, an event was observed that showed that the same requirements should be placed on the fitted pulse of single-pulse fits to avoid a possible loophole. Described fully in Section 2.1.

2. (Benji) The evaluation of the single beam background reveralled that an unused cut, E787_CCDPUL, had an unintended effect on the CCDPUL cut. Described fully in Section 2.2.

3. (Benji) A coding error affected the muon normalization branch. Described fully in Section 2.3.

4. (Benji) Deprecated cuts related to target dE/dx were inadvertantly applied in the beam normalization branch. Described fully in Section 2.4.

5. (Benji) The multiplexing of low-gain CCD fibers was not correctly taken into account. Described fully in Section 2.5.

2.1 CCDBADTIM fix

2.2 E787_CCDPUL story

2.3 Muon background story

2.4 Beam background story

2.5 CCD multiplexing story

3 $K_{\pi 2}$-Scatter background

3.1 $K^+ \to \pi^+\pi^o$ Target Scatters

The $K_{\pi 2}$ decay, where the π^+ scatters in the target, is the dominant background for the $\pi\nu\overline{\nu}(2)$ analysis [2]. As it has been shown with Monte Carlo simulations [4] , the photon distribution from the π^o decay is more uniform in polar angle for events where the π^+ has scattered in the target, than for unscattered ones. Therefore, the PV rejection for TG scatter events is expected to be different than that for $K_{\pi 2}$ events in the peak. The

CLASS	TGCUTS
1	All cuts, KP2BOX
2	$\overline{CCDPUL}$, $\overline{EPIONK}$
3	$\overline{CCDPUL}$, $\overline{EPIONK}$, all others
4	CCDPUL, EPIONK, TGZFOOL, EIC, OPSVETO, $\overline{OTHERS}$
5	$\overline{CCDPUL}$, $\overline{EPIONK}$, $\overline{CHI567}$, $\overline{VERRNG}$
6	$\overline{CCDPUL}$, $\overline{EPIONK}$, $\overline{CHI567}$, $\overline{VERRNG}$, all others
7	$\overline{CHI567}$, $\overline{VERRNG}$
8	$\overline{CHI567}$, $\overline{VERRNG}$, all others
9	$\overline{CCDPUL}$, $\overline{EPIONK}$, $\overline{CHI567}$, $\overline{VERRNG}$, KIC, PIGAP, TARGF, TPICS
10	$\overline{B4EKZ}$
11	$\overline{B4EKZ}$, all others
12	$\overline{CCDPUL}$, $\overline{EPIONK}$, $\overline{B4EKZ}$
13	$\overline{CCDPUL}$, $\overline{EPIONK}$, $\overline{B4EKZ}$, all others

Table 2: Definition of the classes of events (2-13) used to measure the PV rejection in the $\pi\nu\overline{\nu}(2)$ kinematic box. Class 1 events have passed all the TG quality cuts, therefore they are required to be in the $K_{\pi 2}$ kinematic box as to not look in the signal region. All Classes that have either CCDPUL applied or CCDPUL inverted have the three associated safety cuts (CCDBADFIT, CCDBADTIM and CCD31FIB) applied. The nomenclature $\overline{CCDPUL}$, $\overline{EPIONK}$ means $\overline{CCDPUL} + \overline{EPIONK}$.

π^+ kinematics cannot be used in the bifurcation study, since the PV rejection has to be measured inside the $\pi\nu\overline{\nu}(2)$ kinematic box.

3.1.1 Rejection Branch

The other set of cuts used to suppress this background are the target quality cuts (TGCUT06). These eliminate events with evidence of a scattered pion in the target, either the scatter occurred outside the Kaon fibers (scatters visible in xy, or "xy-scatters") or inside them (events where the π^+ started in the beam direction and then scattered into the detector acceptance, or "z-scatters"). The two categories are not mutually exclusive. By inverting some of these cuts and applying others, samples with varying mixtures of xy- and z-scatters can be created for the rejection branch. These samples will be contaminated to an extent with K_{e4}, $K_{\pi 2\gamma}$ and Charge Exchange background, but the contamination is shown to be small [3]. Thirteen such "classes" were used, described in Table 2, and the PV rejection was measured on them in the $\pi\nu\overline{\nu}(2)$ kinematic box (Table 3) . The PV rejections measured for different classes are consistent with each other within statistical uncertainties.

For the final PV rejection, class 12 was used, because it had adequate statistics and it is expected to be the richest in z-scatters, since the cuts that mainly attack them are inverted: CCDPUL and EPIONK cut events with large pulses in the kaon fibers at trs, and B4EKZ rejects events in which the z position of the decay vertex found by the UTC does not agree with the kaon energy deposit (and thus path length) in the

Loose Rejection Branch - Loose PNN2 Box + PV60					
CLASS		bef. PV	af. PV	PV Rejection	Background
2	1/3	24416	9	2712.9±904.1	0.556±0.187
	2/3	49093	22	2231.5±475.7	0.751±0.162
3	1/3	2691	3	897.0±517.6	1.684±0.976
	2/3	5285	2	2642.5±1868.2	0.634±0.449
4	1/3	4225	3	1408.3±812.8	1.072±0.621
	2/3	8194	2	4097.0±2896.7	0.409±0.289
5	1/3	29978	12	2498.2±721.0	0.604±0.177
	2/3	60038	24	2501.6±510.5	0.669±0.138
6	1/3	4066	3	1355.3±782.2	1.114±0.645
	2/3	8182	3	2727.3±1574.3	0.614±0.355
7	1/3	24574	6	4095.7±1671.8	0.369±0.151
	2/3	49636	19	2612.4±599.2	0.641±0.148
8	1/3	357	0	357.0±356.5	4.239±4.249
	2/3	633	0	633.0±632.5	2.649±2.652
9	1/3	23798	10	2379.8±752.4	0.634±0.203
	2/3	47585	21	2265.9±494.4	0.739±0.163
10	1/3	11037	4	2759.2±1379.4	0.547±0.275
	2/3	22037	10	2203.7±696.7	0.760±0.241
11	1/3	46	0	46.0±45.5	33.533±33.939
	2/3	61	0	61.0±60.5	27.900±28.145
12	1/3	26362	10	2636.2±833.5	0.573±0.183
	2/3	52720	23	2292.2±477.8	0.731±0.154
13	1/3	3211	3	1070.3±617.7	1.411±0.818
	2/3	6216	2	3108.0±2197.3	0.539±0.381

Table 3: The rejection branch for the $K_{\pi 2}$ TG scatter background in the loose box: PV rejection using the loose photon veto (PV60) for the $\pi\nu\overline{\nu}(2)$ box and the resulting background. The same setup cuts as in the loose normalization branch (Table 7) are applied.

Tight Rejection Branch - Loose PNN2 Box + PV30

CLASS		bef. PV	af. PV	PV Rejection	Background
2	1/3	24416	3	8138.7±4698.6	0.093±0.054
	2/3	49093	11	4463.0±1345.5	0.169±0.052
3	1/3	2691	1	2691.0±2690.5	0.281±0.282
	2/3	5285	2	2642.5±1868.2	0.286±0.203
4	1/3	4225	0	4225.0±4224.5	0.179±0.179
	2/3	8194	2	4097.0±2896.7	0.185±0.131
5	1/3	29978	4	7494.5±3747.0	0.101±0.051
	2/3	60038	12	5003.2±1444.1	0.151±0.044
6	1/3	4066	1	4066.0±4065.5	0.186±0.186
	2/3	8182	2	4091.0±2892.4	0.185±0.131
7	1/3	24574	1	24574.0±24573.5	0.031±0.031
	2/3	49636	8	6204.5±2193.4	0.122±0.043
8	1/3	357	0	357.0±356.5	2.124±2.131
	2/3	633	0	633.0±632.5	1.196±1.198
9	1/3	23798	3	7932.7±4579.6	0.095±0.055
	2/3	47585	11	4325.9±1304.2	0.175±0.053
10	1/3	11037	1	11037.0±11036.5	0.069±0.069
	2/3	22037	3	7345.7±4240.7	0.103±0.060
11	1/3	46	0	46.0±45.5	16.800±17.020
	2/3	61	0	61.0±60.5	12.600±12.717
12	1/3	26362	4	6590.5±3295.0	0.115±0.058
	2/3	52720	11	4792.7±1444.9	0.158±0.048
13	1/3	3211	1	3211.0±3210.5	0.236±0.236
	2/3	6216	2	3108.0±2197.3	0.243±0.172

Table 4: The rejection branch for the $K_{\pi 2}$ TG scatter background in the tight box: PV rejection using the tight photon veto (PV30) for the $\pi\nu\overline{\nu}(2)$ box and the resulting background. The same setup cuts as in the tight normalization branch (Table 8) are applied.

target. Both these signatures are characteristic of a decay pion that started in the beam direction in the kaon fiber, and then scattered into the detector. The difference in PV rejection between different classes with adequate statistics was used as an estimate for the systematic uncertainty.

Due to the loss of statistics in the rejection branch for the tight box [1], the rejection of the tight (30%) photon veto is measured on a rejection branch that uses the loose versions of the kinematic box, the TD cuts and DELCO. In doing this it is assumed that the rejection of the (30%) photon veto on these classes is the same for the loose and tight cuts. Tables 5 and 6 show that the rejection does not change within statistical error when applying the tight versions of these cuts to the 1/3 and 2/3 data sets respectively. Tables 10 and 11 summarize the photon veto rejections and other values used in the background estimation.

3.1.2 Normalization Branch

In the normalization branch (see Tables 7, 8 and 9), all the cuts in TGCUT06 were applied, and the PV was inverted. Some contamination from $K_{\pi2}$-RS scatters and $K_{\pi2\gamma}$ is expected, but these backgrounds are small compared to $K_{\pi2}$-TG scatters. The ptot distribution of the events remaining in the normalization branch after the inversion of PVCUTPNN2, after the application of all the TGCUT06 except CCDPUL, and after the application of CCDPUL is shown in Figure 1. In the same figure, the ptot distribution of the events in class 12 of the rejection branch is also shown before and after PVCUTPNN2. Both of those distributions look adequately $K_{\pi2}$-scatter-like. Table xxx summarizes the normalization values used for the background estimation.

3.1.3 Background

The $K_{\pi2}$ target scatter background for the loose box $n_{K_{\pi2}-TGscat}(\text{loose})$ is given by

$$n_{K_{\pi2}-TGscat}(\text{loose}) = \frac{N}{R_{PV(60\%)} - 1} \tag{1}$$

, where the results from the 1/3 and 2/3 data sets are scaled to give results for the entire data set. The systematic error comes from the difference in background predicted by the class with the highest and lowest PV rejection, with respect to the central value from CLASS12. Only classes with adequate statistics are considered. The classes chosen for these systematic error bounds are shown in Tables 10 and 11.

For the tight box, the inverted photon veto used in the normalization branch was the loose (60%) photon veto as to not look in the box. Thus the the rejection branch required the use of the loose photon veto and the entire background was scaled by the ratio of the loose and tight (30%) photon vetoes. The tight $K_{\pi2}$ target scatter background

[1]Here, the tight box refers to the application of the tight KIN, TD and DELCO cuts

PV30 Rejection - 1/3 Sample

CLASS	All Loose	Ke4 Box	DELCO6	TDTIGHT	All Tight
2	24416/3 = 8138.67 ± 4698.6	18334/3 = 6111.33 ± 3528.1	21019/1 = 21019 ± 21018.5	18222/1 = 18222 ± 18221.5	11768/0 = 11768 ± 11767.5
3	2691/1 = 2691 ± 2690.5	2067/1 = 2067 ± 2066.5	2161/1 = 2161 ± 2160.5	2032/0 = 2032 ± 2031.5	1249/0 = 1249 ± 1248.5
4	4225/0 = 4225 ± 4224.5	3266/0 = 3266 ± 3265.5	3738/0 = 3738 ± 3737.5	3140/0 = 3140 ± 3139.5	2125/0 = 2125 ± 2124.5
5	29978/4 = 7494.5 ± 3747	22609/4 = 5652.25 ± 2825.9	26115/2 = 13057.5 ± 9232.7	22343/2 = 11171.5 ± 7899.1	14659/1 = 14659 ± 14658.5
6	4066/1 = 4066 ± 4065.5	3164/1 = 3164 ± 3163.5	3293/1 = 3293 ± 3292.5	3062/0 = 3062 ± 3061.5	1923/0 = 1923 ± 1922.5
7	24574/1 = 24574 ± 24573.5	18632/1 = 18632 ± 18631.5	21929/1 = 21929 ± 21928.5	18317/1 = 18317 ± 18316.5	12376/1 = 12376 ± 12375.5
8	357/0 = 357 ± 356.5	298/0 = 298 ± 297.5	306/0 = 306 ± 305.5	253/0 = 253 ± 252.5	186/0 = 186 ± 185.5
9	23798/3 = 7932.67 ± 4579.6	17895/3 = 5965 ± 3443.6	20373/1 = 20373 ± 20372.5	17708/1 = 17708 ± 17707.5	11393/0 = 11393 ± 11392.5
10	11037/1 = 11037 ± 11036.5	7981/1 = 7981 ± 7980.5	9876/1 = 9876 ± 9875.5	8211/1 = 8211 ± 8210.5	5292/1 = 5292 ± 5291.5
11	46/0 = 46 ± 45.5	41/0 = 41 ± 40.5	37/0 = 37 ± 36.5	32/0 = 32 ± 31.5	23/0 = 23 ± 22.5
12	26362/4 = 6590.5 ± 3295	19770/4 = 4942.5 ± 2471	22813/2 = 11406.5 ± 8065.3	19660/2 = 9830 ± 6950.5	12738/1 = 12738 ± 12737.5
13	3211/1 = 3211 ± 3210.5	2430/1 = 2430 ± 2429.5	2565/1 = 2565 ± 2564.5	2408/0 = 2408 ± 2407.5	1448/0 = 1448 ± 1447.5

Table 5: Rejection of the tight (30%) photon veto for the 1/3 sample for the various classes with different combinations of loose and tight versions of the setup cuts: kinematic box cut, TD cuts and DELCO. The 'All Loose' and 'All Tight' columns mean that those three sets of cuts were all loose or all tight. For the other three columns, all the cuts are loose except the one listed, which is tight. The numbers shown are the number of events before the photon veto is applied divided by the number of events remaining after the photon veto is applied and the resulting rejection with statistical error. If there are zero events remaining after the photon veto is applied, the rejection is determined assuming 1 event remained. Note that the events remaining after the photon veto has been applied from all classes in the 'All Loose' column are a sub-set of the events from class 12. The kinematics of these four events have been confirmed to have kinematics that would put them in the ke4-phobic kinematic box.

PV30 Rejection - 2/3 Sample

CLASS	All Loose	Ke4 Box	DELCO6	TDTIGHT	All Tight
2	49093/11 = 4463±1345.5	36824/10 = 3682.4±1164.3	42274/8 = 5284.25±1868.1	36661/8 = 4582.63±1620	23619/6 = 3936.5±1606.9
3	5285/2 = 2642.5±1868.2	4020/2 = 2010±1420.9	4219/2 = 2109.5±1491.3	3975/1 = 3975±3974.5	2427/1 = 2427±2426.5
4	8194/2 = 4097±2896.7	6303/1 = 6303±6302.5	7332/0 = 7332±7331.5	6101/2 = 3050.5±2156.7	4153/0 = 4153±4152.5
5	60038/12 = 5003.17±1444.1	45145/11 = 4104.09±1237.3	52345/8 = 6543.13±2313.2	44837/9 = 4981.89±1660.5	29310/6 = 4885±1994.1
6	8182/2 = 4091±2892.4	6313/2 = 3156.5±2231.6	6659/2 = 3329.5±2354	6197/1 = 6197±6196.5	3909/1 = 3909±3908.5
7	49636/8 = 6204.5±2193.4	37524/7 = 5360.57±2025.9	44381/4 = 11095.3±5547.4	37010/7 = 5287.14±1998.2	24929/4 = 6232.25±3115.9
8	633/0 = 633±632.5	502/0 = 502±501.5	553/0 = 553±552.5	476/0 = 476±475.5	332/0 = 332±331.5
9	47585/11 = 4325.91±1304.2	35522/11 = 3229.27±973.5	40842/8 = 5105.25±1804.8	35596/8 = 4449.5±1573	22734/6 = 3789±1546.7
10	22037/3 = 7345.67±4240.7	15971/2 = 7985.5±5646.2	19757/2 = 9878.5±6984.8	16501/3 = 5500.33±3175.3	10710/2 = 5355±3786.2
11	61/0 = 61±60.5	49/0 = 49±48.5	51/0 = 51±50.5	43/0 = 43±42.5	30/0 = 30±29.5
12	52720/11 = 4792.73±1444.9	39556/10 = 3955.6±1250.7	45660/8 = 5707.5±2017.7	39366/8 = 4920.75±1739.6	25518/6 = 4253±1736.1
13	6216/2 = 3108±2197.3	4667/2 = 2333.5±1649.7	4982/2 = 2491±1761	4665/1 = 4665±4664.5	2828/1 = 2828±2827.5

Table 6: Rejection of the tight (30%) photon veto for the 2/3 sample for the various classes with different combinations of loose and tight versions of the setup cuts: kinematic box cut, TD cuts and DELCO. The 'All Loose' and 'All Tight' columns mean that those three sets of cuts were all loose or all tight. For the other three columns, all the cuts are loose except the one listed, which is tight. The numbers shown are the number of events before the photon veto is applied divided by the number of events remaining after the photon veto is applied and the resulting rejection with statistical error. If there are zero events remaining after the photon veto is applied, the rejection is determined assuming 1 event remained. Note that the events remaining after the photon veto has been applied from all classes in the 'All Loose' column are a sub-set of the events from class 12. The kinematics of these four events have been confirmed to have kinematics that would put them in the ke4-phobic kinematic box.

Loose Normalization Branch

CUT	1/3	2/3
ALL_EVENTS	92709456	92709448
BAD_RUN,KERROR	90192896	90192888
SKIM2/5,RECON	2635077	5264890
PSCUT06	952180	1905107
DELCO3	945357	1891173
TDCUT02 loose	711847	1423458
KINCUT06	417199	833241
PNN2 KIN BOX loose	38835 (10.743)	77831 (10.706)
$\overline{\text{PV60}}$	38820 (1.000)	77795 (1.000)
B4EKZ(IC)	27787 (1.397)	55768 (1.395)
TGZFOOL	27396 (1.014)	55032 (1.013)
EPITG	17250 (1.588)	34859 (1.579)
EPIMAXK	17250 (1.000)	34859 (1.000)
TARGF	14700 (1.173)	29677 (1.175)
DTGTTP	14700 (1.000)	29677 (1.000)
RTDIF	14590 (1.008)	29424 (1.009)
DRP	14388 (1.014)	28982 (1.015)
TGKTIM	14144 (1.017)	28482 (1.018)
EIC	13847 (1.021)	27843 (1.023)
TIC	13847 (1.000)	27843 (1.000)
TGEDGE	13621 (1.017)	27394 (1.016)
TGDEDX	12809 (1.063)	25918 (1.057)
TGENR	12533 (1.022)	25403 (1.020)
PIGAP	12342 (1.015)	25037 (1.015)
TGB4	11082 (1.114)	22562 (1.110)
KIC	11076 (1.001)	22556 (1.000)
PHIVTX	8289 (1.336)	16873 (1.337)
OPSVETO	7238 (1.145)	14793 (1.141)
TGLIKE	6812 (1.063)	13863 (1.067)
TIMKF	5542 (1.229)	11358 (1.221)
NPITG	5542 (1.000)	11358 (1.000)
ALLKFIT	5295 (1.047)	10857 (1.046)
TPICS	5291 (1.001)	10856 (1.000)
EPIONK	4970 (1.065)	10204 (1.064)
CHI567	4143 (1.200)	8514 (1.198)
VERRNG	3455 (1.199)	7055 (1.207)
CHI5MAX	3454 (1.000)	7055 (1.000)
ANGLI	3445 (1.003)	7039 (1.002)
CCDBADFIT	3083 (1.117)	6214 (1.133)
CCDBADTIM	2991 (1.031)	6026 (1.031)
CCD31FIB	2991 (1.000)	6026 (1.000)
CCDPUL	503 (5.946)	1116 (5.400)

Table 7: The normalization branch for the loose $K_{\pi2}$-TG scatter background: events after setup cuts and TGCUTS and their rejection (in brackets) in the $\pi\nu\overline{\nu}(2)$ loose box.

Tight Normalization Branch

CUT	1/3	2/3
ALL_EVENTS	92709456	92709448
BAD_RUN,KERROR	90192896	90192888
SKIM2/5,RECON	2635077	5264890
PSCUT06	952180	1905107
DELCO6	778661	1560187
TDCUT02 tight	428074	858447
KINCUT06	257607	516539
Ke4-phobic KIN BOX	18911 (13.622)	37733 (13.689)
$\overline{\text{PV60}}$	18907 (1.000)	37714 (1.000)
B4EKZ(IC)	13617 (1.388)	27008 (1.396)
TGZFOOL	13437 (1.013)	26631 (1.014)
EPITG	8228 (1.633)	16470 (1.617)
EPIMAXK	8228 (1.000)	16470 (1.000)
TARGF	6914 (1.190)	13831 (1.191)
DTGTTP	6914 (1.000)	13831 (1.000)
RTDIF	6870 (1.006)	13720 (1.008)
DRP	6791 (1.012)	13565 (1.011)
TGKTIM	6761 (1.004)	13502 (1.005)
EIC	6623 (1.021)	13237 (1.020)
TIC	6623 (1.000)	13237 (1.000)
TGEDGE	6535 (1.013)	13079 (1.012)
TGDEDX	6120 (1.068)	12360 (1.058)
TGENR	5988 (1.022)	12102 (1.021)
PIGAP	5883 (1.018)	11909 (1.016)
TGB4	5251 (1.120)	10663 (1.117)
KIC	5248 (1.001)	10660 (1.000)
PHIVTX	3826 (1.372)	7767 (1.372)
OPSVETO	3374 (1.134)	6872 (1.130)
TGLIKE	3176 (1.062)	6426 (1.069)
TIMKF	2621 (1.212)	5357 (1.200)
NPITG	2621 (1.000)	5357 (1.000)
ALLKFIT	2507 (1.045)	5131 (1.044)
TPICS	2504 (1.001)	5130 (1.000)
EPIONK	2321 (1.079)	4727 (1.085)
CHI567	1898 (1.223)	3857 (1.226)
VERRNG	1592 (1.192)	3168 (1.217)
CHI5MAX	1591 (1.001)	3168 (1.000)
ANGLI	1588 (1.002)	3161 (1.002)
CCDBADFIT	1426 (1.114)	2775 (1.139)
CCDBADTIM	1381 (1.033)	2692 (1.031)
CCD31FIB	1381 (1.000)	2692 (1.000)
CCDPUL	252 (5.480)	504 (5.341)

Table 8: The normalization branch for the tight $K_{\pi 2}$-TG scatter background: events after setup cuts and TGCUTS and their rejection (in brackets) in the $\pi\nu\overline{\nu}(2)$ ke4-phobic box. Note that it is the loose 60% photon veto that is inverted for the tight normalization branches.

Loose Normalization Branch in KP2 Kinematic Box		
CUT	1/3	2/3
ALL_EVENTS	92709456	92709448
BAD_RUN,KERROR	90192896	90192888
SKIM2/5,RECON	2635077	5264890
PSCUT06	952180	1905107
DELCO3	945357	1891173
TDCUT02 loose	711847	1423458
KINCUT06	417199	833241
KP2 KIN BOX	337622 (1.236)	674203 (1.236)
$\overline{\text{PV60}}$	337377 (1.001)	673562 (1.001)
B4EKZ(IC)	307443 (1.097)	613750 (1.097)
TGZFOOL	302502 (1.016)	603827 (1.016)
EPITG	265780 (1.138)	529424 (1.141)
EPIMAXK	265780 (1.000)	529424 (1.000)
TARGF	256810 (1.035)	511730 (1.035)
DTGTTP	256803 (1.000)	511722 (1.000)
RTDIF	254618 (1.009)	507370 (1.009)
DRP	253746 (1.003)	505667 (1.003)
TGKTIM	251265 (1.010)	500819 (1.010)
EIC	247096 (1.017)	492280 (1.017)
TIC	247095 (1.000)	492275 (1.000)
TGEDGE	244792 (1.009)	487869 (1.009)
TGDEDX	243294 (1.006)	485094 (1.006)
TGENR	236833 (1.027)	472146 (1.027)
PIGAP	235171 (1.007)	468742 (1.007)
TGB4	221207 (1.063)	440987 (1.063)
KIC	221103 (1.000)	440790 (1.000)
PHIVTX	213725 (1.035)	425722 (1.035)
OPSVETO	204252 (1.046)	406804 (1.046)
TGLIKE	197703 (1.033)	393828 (1.033)
TIMKF	175933 (1.124)	350615 (1.123)
NPITG	175933 (1.000)	350615 (1.000)
ALLKFIT	169905 (1.035)	338574 (1.036)
TPICS	169877 (1.000)	338520 (1.000)
EPIONK	159031 (1.068)	316969 (1.068)
CHI567	138310 (1.150)	275107 (1.152)
VERRNG	129595 (1.067)	257769 (1.067)
CHI5MAX	129595 (1.000)	257769 (1.000)
ANGLI	129524 (1.001)	257629 (1.001)
CCDBADFIT	114548 (1.131)	227724 (1.131)
CCDBADTIM	112107 (1.022)	222903 (1.022)
CCD31FIB	112105 (1.000)	222903 (1.000)
CCDPUL	60775 (1.845)	120985 (1.842)

Table 9: The normalization branch for the $K_{\pi2}$-TG scatter background in the KP2 box: events after setup cuts and TGCUTS and their rejection (in brackets) in the $K_{\pi2}$ box.

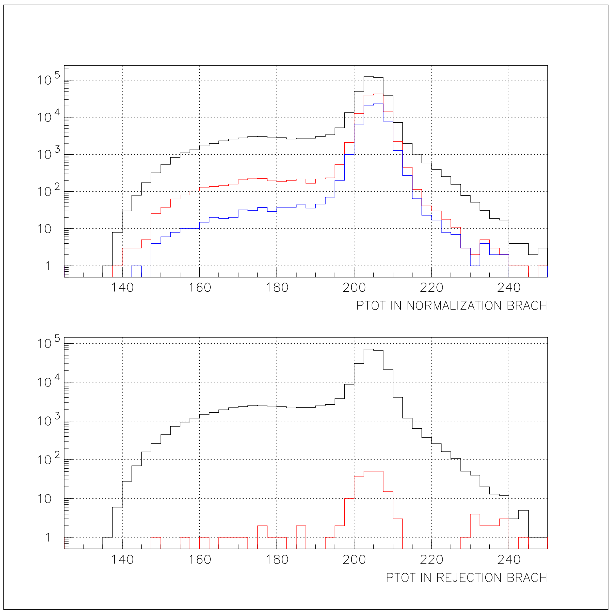


Figure 1: Top: ptot distribution of the events remaining in the normalization branch of the $K_{\pi 2}$ TG scatter study after the inversion of PVCUT (black), after the application of all the TGCUT06 except CCDPUL (red), and after the application of CCDPUL (blue). Bottom: ptot distribution of the events in CLASS12 of the rejection branch of the $K_{\pi 2}$ TG scatter study before (black) and after (red) PVCUT. (Note that these plots were made using 1/3 data.)

Loose $K_{\pi2}$ Target Scatter Summary

	1/3	2/3
	Normalization	
N	503	1116
	Photon Veto Rejection R_{PV60}	
R_{PV60}(CLASS12)	2636.2±833.5	2292.2±477.8
R_{PV60}(max.)	4095.7±1671.8 (CLASS7)	2612.4±599.2 (CLASS7)
R_{PV60}(min.)	2379.8±752.4 (CLASS9)	2203.7±696.7 (CLASS10)
R_{PV60}	$2636.2 \pm 833.5^{+1459.5}_{-256.4}$	$2292.2 \pm 477.8^{+320.2}_{-88.5}$
	Background Estimate: $n_{\rm bg} = N/(R_{PV60} - 1)$	
$n_{\rm bg}$	$0.573 \pm 0.183^{+0.062}_{-0.204}$	$0.731 \pm 0.154^{+0.029}_{-0.090}$

Table 10: The summary of the loose $K_{\pi2}$ target-scatter background estimation. For the photon veto rejection R_{PV60} and background estimate n_{bg}, the first error is statistical and the second error systematic. The maximum and minimum 60% photon veto rejections are labeled to show which class was used to determine the systematic errors in R_{PV60} and n_{bg}.

$n_{K_{\pi2}-TGscat}$(tight) is given by

$$n_{K_{\pi2}-TGscat}(\text{tight}) = \frac{N}{R_{PV(60\%)} - 1}\left(\frac{R_{PV(60\%)}}{R_{PV(30\%)}}\right), \tag{2}$$

where the results from the 1/3 and 2/3 data sets are scaled to give results for the entire data set. The lower and upper bounds on the systematic error again come from the difference in background predicted by the class with the highest and lowest PV rejections with respect to CLASS12. Only classes with adequate statistics are considered. For the purposes of determining the bounds on the systematic error, the difference in photon veto rejection for CLASS12 between the “All Loose” and “Ke4-phobic kinematic box” setups cuts (Table 5 and 6) is treated as another class.

Tables 10 and 11 show the summary of all values used to determine these loose and tight backgrounds respectively.

3.2 $K^+ \rightarrow \pi^+\pi^o$ Range Stack Scatters

Pions from the $K_{\pi2}$ decay can also undergo inelastic scattering in the Range Stack and fall into the $\pi\nu\overline{\nu}(2)$ kinematic box by losing energy in the scattering process. However, for these events to be a background for this analysis, the pion momentum also has to

Tight $K_{\pi2}$ Target Scatter Summary		
	1/3	2/3
Normalization		
N	252	504
Photon Veto Rejection R_{PV30}		
R_{PV30}(CLASS12)	6590.5±3295.0	4792.7±3295.0
R_{PV30}(max.)	8138.7±4698.6 (CLASS2)	6204.5±2193.4 (CLASS7)
R_{PV30}(min.)	4942.5±2471.0 (KE4-PHOBIC)	3955.6±1250.7 (KE4-PHOBIC)
R_{PV30}	$6590.5 \pm 3295.0^{+1548.2}_{-1648.0}$	$4792.7 \pm 1444.9^{+1411.8}_{-837.1}$
Photon Veto Rejection R_{PV60}		
R_{PV60}[1]	$2636.2 \pm 833.5^{+1459.5}_{-256.4}$	$2292.2 \pm 477.8^{+320.2}_{-88.5}$
Background Estimate: $n_{\rm bg} = \frac{N}{R_{PV60}-1}\left(\frac{R_{PV60}}{R_{PV30}}\right)$		
$n_{\rm bg}$	$0.115 \pm 0.058^{+0.038}_{-0.022}$	$0.158 \pm 0.048^{+0.033}_{-0.036}$

Table 11: The summary of the tight $K_{\pi2}$ target-scatter background estimation. For the photon veto rejection R_{PV60} and background estimate n_{bg}, the first error is statistical and the second error systematic. The maximum and minimum 30% photon veto rejections are labeled to show which class was used to determine the systematic errors in R_{PV60} and n_{bg}. The rejection for the 60% photon veto is taken from Table 10

RS-Scat Rejection Branch - Loose Box

CUT	KP2BOX		KP2-PBOX PNN2-REBOX	
	1/3	2/3	1/3	2/3
PBOX from KP2BOX	92873	185427	719	1535
LAYER14	92820	185323	719	1535
FIDUCIAL	85639	170856	649	1385
UTCQUAL	82943	165371	636	1336
RNGMOM	82237	163994	636	1336
RSDEDX	71806	143262	113	267
PRRF	60810	121092	81	191
PVCUT	35	107	0	0

Table 12: The loose rejection branch for $K_{\pi 2}$-RS scatters. PBOX is the momentum cut and RE BOX the range and energy cut.

be mis-measured and the photons from the π^o decay have to be missed. Therefore, this background is expected to be smaller compared to the $K_{\pi 2}$ target scattered background. It should be noted that these background events are already included in the normalization branches in Tables 7 and 8[2], but they are not included in the rejection branch in Table 3 because the target cuts were reversed to measure this PV rejection. The $K_{\pi 2}$ events which scattered in the RS should be assigned the same Photon Veto rejection as the $K_{\pi 2}$ peak events, since the pion did not scatter in the target. The method used to determine this background was originally formulated by Milind et al. [2].

The most effective cuts against this background are the Range Stack track quality cuts RSDEDX and PRRF (collectively referred to as RSCT), the BOX cut on *ptot* and the Photon Veto cut. The SETUP cuts are the same as the $K_{\pi 2}$ target scatter normalization branch. Tables 12 and 13 contain events in the $K_{\pi 2}$ momentum peak. Events with the momentum of the $K_{\pi 2}$ peak events, but lowered in range and energy are assumed to have scattered in the Range Stack.

The efficiency ϵ_{RSCT} and the rejection R_{RSCT} of the RSCT cuts can be determined from the RS-Scatter Rejection Tables 12 and 13. The efficiency ϵ_{RSCT} is determined from the 'KP2BOX' column and the rejection R_{RSCT} from the 'KP2-PBOX PNN2-REBOX' column.

$$\epsilon_{RSCT} = N_{\mathrm{PRRF}}/N_{\mathrm{RNGMOM}} \quad (3)$$
$$R_{RSCT} = N_{\mathrm{RNGMOM}}/N_{\mathrm{PRRF}} \quad (4)$$

Tables 14 and 15 show the normalization branch. The RSCT cut is reversed and all other cuts are applied. The various contributions to the total *norm_rs* events left at the the end of the branch have to be considered in order to calculate the background of interest. The largest component of this sample comes from scattering in the target that

[2]Correcting the normalization of $K_{\pi 2}$-TG scatters for $K_{\pi 2}$-RS scatters does not make a significant difference in the background, given the statistical uncertainty.

RS-Scat Rejection Branch - Tight Box				
CUT	KP2BOX		KP2-PBOX KE4-PHOBIC REBOX	
	1/3	2/3	1/3	2/3
PBOX from KP2BOX	61794	123717	345	829
LAYER14	61760	123650	345	829
FIDUCIAL	57037	114044	308	758
UTCQUAL	55234	110397	303	730
RNGMOM	54757	109502	303	730
RSDEDX	47928	95963	63	168
PRRF	40750	81415	44	120
PVCUT	11	36	0	0

Table 13: The tight rejection branch for $K_{\pi 2}$-RS scatters. PBOX is the momentum cut and RE BOX the range and energy cut.

RS-Scat Normalization Branch - Loose Box				
CUT	KP2BOX		PNN2BOX	
	1/3	2/3	1/3	2/3
$\overline{\text{RSDEDX}}$.or.$\overline{\text{PRRF}}$	25043	50009	218	404
LAYER14	25023	49971	218	404
FIDUCIAL	22558	45187	203	382
UTCQUAL	21650	43371	180	345
RNGMOM	21427	42902	154	279
$\overline{\text{PVCUT60}}$	21418	42876	154	279

Table 14: The loose normalization branch for $K_{\pi 2}$-RS scatters.

RS-Scat Normalization Branch - Tight Box				
CUT	KP2BOX		KE4-PHOBIC BOX	
	1/3	2/3	1/3	2/3
$\overline{\text{RSDEDX}}$.or.$\overline{\text{PRRF}}$	16389	32792	82	155
LAYER14	16377	32768	82	155
FIDUCIAL	14774	29569	76	149
UTCQUAL	14164	28392	69	133
RNGMOM	14007	28087	67	121
$\overline{\text{PVCUT60}}$	14000	28073	67	121

Table 15: The tight normalization branch for $K_{\pi 2}$-RS scatters.

	Loose		Tight	
	1/3	2/3	1/3	2/3
	$\epsilon_{RSCT} = N_{\mathrm{PRRF}}/N_{\mathrm{RNGMOM}}$			
N_{PRRF}	60810	121092	40750	81415
N_{RNGMOM}	82237	163994	54757	109502
ϵ_{RSCT}	0.739±0.002	0.738±0.001	0.744±0.002	0.744±0.001
	$R_{RSCT} = N_{\mathrm{RNGMOM}}/N_{\mathrm{PRRF}}$			
N_{RNGMOM}	636	1336	303	730
N_{PRRF}	81	191	44	120
R_{RSCT}	7.852±0.815	6.995±0.469	6.886±0.960	6.083±0.508
	Normalization Numbers			
norm_tg	503	1116	252	504
norm_rs	154	279	67	121
N_{rs}	-3.575±2.308	-20.635±4.014	-3.540±1.878	-11.159±3.081
	Photon Veto Rejection R_{PV60} ($\mathrm{K}_{\pi2}$ peak)			
Before PV	60810	121092	40750	81415
After PV	35	107	11	36
R_{PV60}	1737.4±293.6	1131.7±109.4	3704.6±1116.8	2261.5±376.8
	$n_{\mathrm{bg}} = N_{rs}/(R_{PV60} - 1)$			
n_{bg}	-0.0062±0.0041	-0.0274±0.0059	-0.0029±0.0017	-0.0074±0.0024

Table 16: The summary of the $K_{\pi2}$ range-stack scatter background estimation.

contaminated the RSCT reversed sample because of the inefficiency of the RSCT cuts. On the other hand, the total *norm_tg* events left at the end of the $K_{\pi 2}$ target scatter normalization branch (Tables 7 and 8) have a target scattered (N_{tg}) and a RS scattered (N_{rs}) component. We can write

$$\begin{aligned} N_{tg} + N_{rs} &= norm\_tg \\ \frac{1-\epsilon_{RSCT}}{\epsilon_{RSCT}} \times N_{tg} + (R_{RSCT} - 1) \times N_{rs} &= norm\_rs \end{aligned} \quad (5)$$

Note that the form of the second equation has been corrected from that as used by Milind et al. [2]. As seen in Table 16, solving this system of equations gives negative solutions for the range stack scattered component N_{rs} for both the loose and tight boxes in the 1/3 and 2/3 data sets.

The final background from the RS scattered events can be determined from N_{rs} and the $K_{\pi 2}$ peak Photon Veto rejection from CLASS1 as shown:

$$n_{K_{\pi 2}-RSscat} = (3 \text{ or } 3/2) \times \frac{N_{rs}}{R_{PV-K_{\pi 2}peak} - 1} \quad (6)$$

where the normalization factor of 3 is used for the 1/3 data sample and the normalization factor of 3/2 for the 2/3 data sample.

4 $K_{\pi 2\gamma}$ Background

Needs to be written for 2/3 analysis.

5 Beam Background

The statistics of the beam background samples are very limited. Efforts went into obtaining comparatively higher statistic samples by loosing cuts. Within all beam background studies, 1-beam and 2-beam, the PV was applied with the same cut parameters as was performed in PNN1; applying PV_{pnn2} will remove all events well before all other cuts are applied. Therefore, we must scale by $\frac{A_{PV_{pnn2}}}{A_{PV_{pnn1}}}$ where $A_{PV_{pnn1}} = 0.925$ and $A_{PV_{pnn2}} = 0.639$ for the loose signal region and $A_{PV_{pnn2}} = 0.356$ for the tight region. The value for $A_{PV_{pnn1}} = 0.925$ was measured with the PNN2 setup cuts, as shown in Table **??**. Also, note that the acceptances shown here ($A_{PV_{pnn2}}, A_{PV_{pnn1}}$) are the PV subsystems which are included in pvcut02_new.function (TG, IC,VC,CO,MC,EC,RD,BV,BVL for both pnn1 and pnn2 and also including ADPV, earlyBV, DS,earlyBVL for pnn2). Scaling by the PV acceptance-loss is justified by beam backgrounds being independent upon the PV cuts (except for ADPV on the 2-beam). That is, there is no expectation of additional rejection against these background for the PV cuts (except for the ADPV cut in the 2-beam background which is discussed in Section 5.2).

For comparison, the beam background is explicitly measured in the tight region in the following sections. However, PNN2 will be utilizing the value from scaling the background in the loose region. Further, details of the beam background were written in Ref. [5].

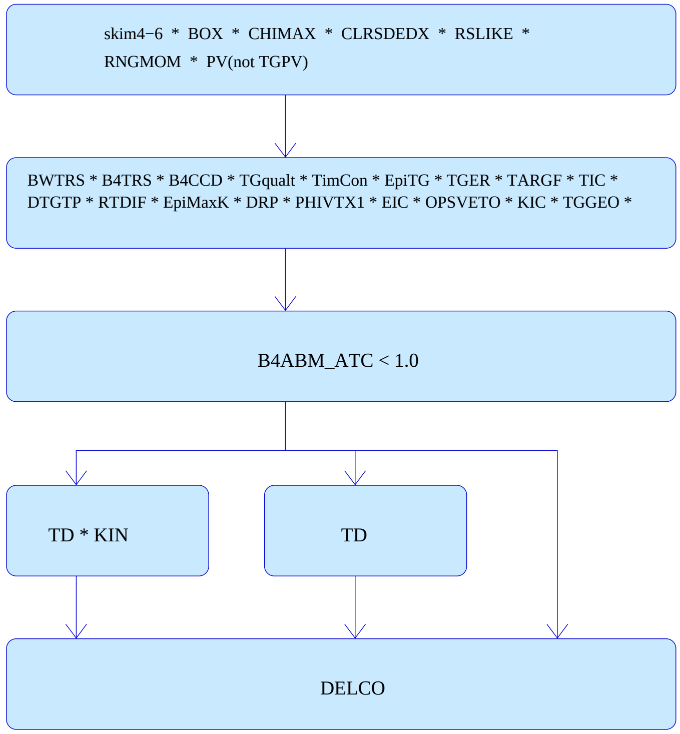


Figure 2: **1-Beam Rejection Bifurcation**. The additional branches in this rejection bifurcation is cleaning up the sample with additional cuts at the expense of reducing statistics. *DELCO*=DEL3 OR DELC6 depending on what signal region is being studied.

5.1 Single-Beam Background

The single-beam background is bifurcated with DELCO. In the normalization brach, we invert the loosest version of DELCO which is DELC3. This is to preserve the blind analysis. The rejection branch as shown in Fig. 2 has three branches. This follows what was done in PNN1; higher statistics samples were obtained by not applying kinematic (KIN) and/or TD cuts. Due to the 1 beam background being relatively small compared to the other beam backgrounds (and very small compared to Kpi2 scattering) a conservative estimate was chosen, i.e. the cleanest sample (with TD*KIN applied) with the lowest statistics was used in the final measurement.

$$N_{1bm} = 3 \times \frac{A_{PV_{pnn2}}}{A_{PV_{pnn1}}} \times \frac{N_{1bm}}{R_{delco} - 1} \tag{7}$$

$$\begin{aligned} N_{1bm_{loose}} &= 3 \times \frac{0.639}{0.925} \times \frac{5.0 \pm 2.2}{(6398.0 \pm 6397.5) - 1} \\ &= (1.58 \pm 1.58) \times 10^{-3} \end{aligned} \tag{8}$$

Setup Branch	$1/3\ Rej^{loose}_{DELCO}$	$1/3\ Rej^{tight}_{DELCO}$	$2/3\ Rej^{loose}_{DELCO}$
Loose Setup	10590.0 ± 7487.9 (2)	17800.0 ± 17799.5 (1)	3190.8 ± 884.8 (13)
TD	17625.0 ± 17624.5 (1)	10743.0 ± 10742.5 (1)	4931.3 ± 1863.7 (7)
TD · KIN	$\mathbf{6398.0 \pm 6397.5}$ **(1)**	$\mathbf{3857.0 \pm 3856.5}$ **(1)**	$\mathbf{6179.5 \pm 4369.2}$ **(2)**

Table 17: **1-Beam Rejection Summary**. Each row is a different branch to measure the DELCO rejection with samples becoming cleaner for each subsequent row. First number is the rejection. The number is parenthesis is the number of events remaining that the rejection is based upon. The minimum rejection is used in calculation of the 1-BM background for a conservative estimate.

	$1/3\ Norm^{loose}_{1bm}$	$1/3\ Norm^{tight}_{1bm}$	$2/3\ Norm^{loose}_{1bm}$
$\overline{DELC}3$	5.0 ± 2.2	2.0 ± 1.4	23.0 ± 4.8

Table 18: **1-Beam Normalization Summary** In the 1-bm normalization, DECL3 was inverted for both the loose and tight regions. PV_{pnn1} was applied as a loose PV cut instead of the loose and tight versions of PV_{pnn2}.

$$
\begin{aligned}
N_{1bm_{tight}} &= 3 \times \frac{0.356}{0.925} \times \frac{2.0 \pm 1.4}{(3857.0 \pm 3856.5) - 1} \\
&= (1.58 \pm 1.58) \times 10^{-3} \qquad (9)
\end{aligned}
$$

If we "measure" the tight value from scaling from 1-beam loose value, we obtain the following: Note that the factor of 3 is included in the value of $N_{1bm_{loose}}$.

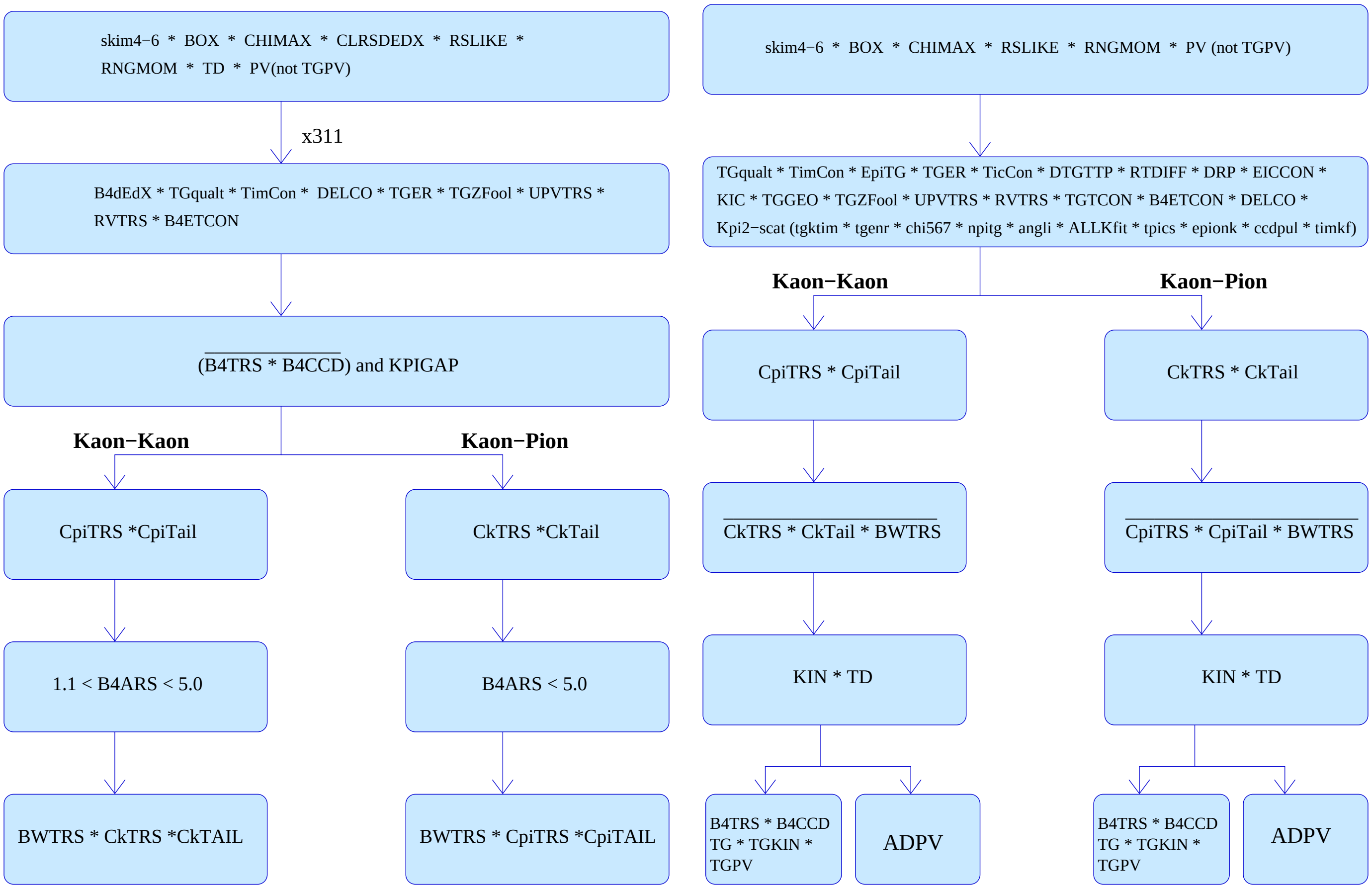
$$
N^{scaled}_{1bm_{tight}} = \frac{A_{PV_{tight}}}{A_{PV_{loose}}} \times \frac{A_{TD_{tight}}}{A_{TD_{loose}}} \times \frac{A_{BOX_{tight}}}{A_{BOX_{loose}}} \times \frac{A_{DELCO_{tight}}}{A_{DELCO_{loose}}} \times N_{1bm_{loose}} \qquad (10)
$$

$$
\begin{aligned}
N^{scaled}_{1bm_{tight}} &= \frac{0.356}{0.639} \times \frac{0.704}{0.942} \times (0.68) \times \frac{0.704}{0.857} \times 0.00157 \\
&= (0.35 \pm 0.35) \times 10^{-3} \qquad (11)
\end{aligned}
$$

$N^{scaled}_{1bm_{tight}}$ is consistent with $N_{1bm_{tight}}$. If we use the $Rej_{delco} = 6239$ from the loose region (which has more statistics) for the tight region then $N_{1bm_{tight}} = 0.33 \times 10^{-3}$.

5.2 Double-Beam Background

The normalization of double-beam background measurement was modified since Ref. [5]. Previously, ADPV was not applied as a cut, since PV_{pnn1} was applied which did not include ADPV. For PNN2, a correction for the difference between PNN1 and PNN2 Photon Veto was applied by multiplying by the ratio of the acceptance of these two cuts. However, ADPV is known to have rejection above acceptance loss for 2-beam background. Therefore, previous studies overestimated the 2-beam background due to the additional rejection of ADPV. The solution that was devised to solve this issue was to change the



(a) Rejection (b) Normalization

Figure 3: **2-Beam Bifurcations (Kaon-Kaon and Kaon-Pion).** *DELCO* changes depending on the study. *DELCO*=DEL3 OR DELC6 depending on what signal region is being studied.

bifurcation of the double beam (KK and Kpi) branches, see bottom of Fig. 3(b). This also reduced an previous issue with correlation of the B4 and TG cuts which were the cuts which were bifurcated previously. The ADPV should be less correlated with the B4 and TG compared to the bifurcation strategy employed in E949-PNN1 [6].

Scale by acceptance by $PV_{no\ AD}$ due to applying ADPV in the normalization branch. $PV_{no\ AD}$ is 0.673 (0.673) for loose (tight) which is determined by Table **??**. Table 19 corresponds to Fig. 3(a) and Table 20 corresponds to Fig. 3(b).

5.2.1 2-beam results

5.2.2 KK-beam background

$$N_{KK} = 3 \times \frac{A_{PV_{noAD}}}{A_{PV_{pnn1}}} \times \frac{\left(\frac{n_{KK}}{r_{KK}}\right)}{R_{KK} - 1} \quad (12)$$

Rejection of	1/3 Rej_{KK}^{loose}	2/3 Rej_{KK}^{tight}	2/3 Rej_{KK}^{loose}
$R_{KK}:\ BWTRS \cdot CkTRS \cdot CkTail$	61.9 ± 9.8 (39)	59.9 ± 12.7 (22)	54.3 ± 5.8 (86)
$R_{Kpi}:\ BWTRS \cdot CpiTRS \cdot CpiTail$	352.5 ± 124.5 (8)	274.3 ± 111.8 (6)	264.9 ± 57.7 (21)

Table 19: **2-Beam Rejection Summary**. First number is the rejection. The number in parenthesis is the number of events remaining that the rejection is based upon. K-K is the case where two Kaons are entering the beam. K-pi is the case where we have a Kaon and a Pion entering. $\overline{B4TRS \cdot B4CCD}\ AND\ KPIGAP$ is applied to select the rejection sample. KIN, TD and many other cuts listed in these flow charts are composite cuts.

$Norm.\ branches$	1/3 loose	1/3 tight	2/3 loose
$n_{KK}:\ TG \cdot TGPV \cdot B4$	8.0 ± 2.8	1.0 ± 1.0	19.0 ± 4.36
$r_{KK}:\ ADPV$	7.3 ± 2.6	7.3 ± 3.9	$5.41\pm$
N_{KK}	1.1 ± 0.55	0.136 ± 0.136	$3.51\pm$
$n_{Kpi}:\ TG \cdot TGPV \cdot B4$	10.0 ± 3.2	3.0 ± 1.7	3.0 ± 1.73
$r_{Kpi}:\ ADPV$	21.0 ± 10.2	45.0 ± 44.5	$6.84\pm$
N_{Kpi}	0.5 ± 0.3	0.1 ± 0.1	$0.438\pm$

Table 20: **2-Beam Normalization Summary**. The 2-BM Normalization has 2 branches that are further bifurcated. $K\text{-}K_{r,n}$, $K\text{-}pi_{r,n}$ are the results of the bifurcations, r=rejection, n=normalization, which we used to determine the last two rows. N_{K-K} *and* N_{K-pi} are the 2-BM normalization values which are employed in the calculation of the beam-background. For KK (Kpi), $\overline{CkTRS \cdot CkTAIL \cdot BWTRS}$ ($\overline{CpiTRS \cdot CpiTAIL \cdot BWTRS}$) is applied

$$\begin{aligned} N_{KK_{loose}} &= 3 \times \frac{0.673}{0.925} \times \frac{(\frac{8}{51/7.})}{61.9-1} \\ &= (39.3 \pm 19.5) \times 10^{-3} \end{aligned} \tag{13}$$

$$\begin{aligned} N_{KK_{tight}} &= 3 \times \frac{0.3752}{0.925} \times \frac{(\frac{1}{22/3.})}{59.9-1} \\ &= (2.82 \pm 2.82) \times 10^{-3} \end{aligned} \tag{14}$$

5.2.3 $K\pi$-beam background

- Only measure the background in the data before the $\pi\nu\nu(2)$ C_π trigger change. This entails scaling by 2.54 to extrapolate to the full running period.
- Scale by the acceptance for the PV_{pnn1} cut.
- Do not apply ADPV due to lack of statistics (lower statistics compared to KK due to C_π trigger change.

$$N_{K\pi} = 3 \times 2.54 \times \frac{A_{PV_{pnn2}}}{A_{PV_{pnn1}}} \times \frac{(\frac{n_{K\pi}}{r_{K\pi}})}{R_{K\pi} - 1} \tag{15}$$

$$\begin{aligned} N_{K\pi_{loose}} &= 3 \times 2.54 \times \frac{0.639}{0.925} \times \frac{(\frac{10}{84/4.})}{352.5 - 1} \\ &= (7.73 \pm 7.73) \times 10^{-3} \end{aligned} \tag{16}$$

$$\begin{aligned} N_{K\pi_{tight}} &= 3 \times 2.54 \times \frac{0.356}{0.925} \times \frac{(\frac{3}{45/1.})}{274.3 - 1} \\ &= (0.715 \pm 0.715) \times 10^{-3} \end{aligned} \tag{17}$$

5.3 Beam Background Summary

$(\times 10^{-3})$	k034	e787	1/3 loose	1/3 tight	2/3 loose
1-BM	3.86 ± 2.36	1.66 ± 1.66	1.57 ± 1.57	0.35 ± 0.35	3.86 ± 3.86
2-BM KK	0.983 ± 0.983	145.9 ± 145.9	39.3 ± 19.5	2.82 ± 2.82	$71.8\pm$
2-BM Kpi	0.106 ± 0.106	19.7 ± 19.7	7.73 ± 7.73	0.715 ± 0.715	4.61 ± 4.61
2-BM	1.14 ± 1.14	165.6 ± 165.6	43.8 ± 31.7	31.7 ± 31.7	$76.4\pm$
$Total\ Beam$	5.00 ± 2.62	167.3 ± 167.3	45.37 ± 20.08	3.72 ± 3.22	$78.0\pm$

Table 21: **Total Beam-Background.** Scaled to the 3/3 sample. k034 column is the result of e949-pnn1 analysis [6]. e787 is the result of the e787-PNN2 analysis [7]. The other columns are current results that are expanded upon throughout the rest of the tables. The errors are statistical. KB_{live} for k034 is 1.77×10^{12} and for e787 is 1.71×10^{12} . e787 background has been scaled up accordingly for comparison purposes.

6 Muon Background

The muon background is expected to come mainly from $K^+ \rightarrow \mu^+\nu\gamma$ and $K^+ \rightarrow \pi^0\mu^+\nu$ decays ($K_{\mu2\gamma}$) in the PNN2 kinematic region. This background is expected to be small, because for these processes to be confused with signal, both the muon has to be misidentified as a π^+ and the photon(s) have to be missed. The cuts used to suppress the muon background are the $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ decay sequence cuts (TDCUT02) and the pion-muon kinematic separation cut, RNGMOM.

Cuts	1/3 Loose	2/3 Loose
badrun	12892493 (0.00)	25768044 (0.00)
Tnono	12823737 (1.01)	25631012 (1.01)
DUPEV	12823737 (1.00)	25631012 (1.00)
rdtrk	12823737 (1.00)	25631012 (1.00)
trktim	12823737 (1.00)	25631012 (1.00)
target	12823737 (1.00)	25631012 (1.00)
stlay	12823737 (1.00)	25631012 (1.00)
utc	12823737 (1.00)	25631012 (1.00)
rdutm	12823737 (1.00)	25631012 (1.00)
badstc	12823737 (1.00)	25631012 (1.00)
pdc	12823737 (1.00)	25631012 (1.00)
bfdedx	11409696 (1.12)	22803548 (1.12)
bwtrs	8868972 (1.29)	17724324 (1.29)
bftrs	8220794 (1.08)	16427904 (1.08)
bfetcon	8135020 (1.01)	16256902 (1.01)
bfccd	8036604 (1.01)	16060975 (1.01)
cpitrs	7688327 (1.05)	15362723 (1.05)
cpitail	7684992 (1.00)	15355998 (1.00)
cktrs	5335463 (1.44)	10660536 (1.44)
cktail	5062839 (1.05)	10118608 (1.05)
tgqualt	4815371 (1.05)	9625818 (1.05)
timcon	4789227 (1.01)	9573254 (1.01)
tgtcon	4683555 (1.02)	9361755 (1.02)
rvtrs	4666832 (1.00)	9328367 (1.00)
upvtrs	4585317 (1.02)	9165183 (1.02)
delco	3976305 (1.15)	7947312 (1.15)
tggeo	2926088 (1.36)	5848653 (1.36)
combops	2926088 (1.00)	5848653 (1.00)
RNGMOM	1209061 (2.42)	2414194 (2.42)
bfekz	1014599 (1.19)	2025353 (1.19)
epitg	844535 (1.20)	1685549 (1.20)
epimaxk	844535 (1.00)	1685549 (1.00)
targf	806399 (1.05)	1610360 (1.05)
tger	804818 (1.00)	1607188 (1.00)
dtgttp	804809 (1.00)	1607170 (1.00)
rtdif	797785 (1.01)	1592799 (1.01)
drp	796019 (1.00)	1589231 (1.00)
tgktim	789942 (1.01)	1577192 (1.01)
eiccon	755694 (1.05)	1508824 (1.05)
ticcon	755690 (1.00)	1508815 (1.00)
tgedge	750037 (1.01)	1497404 (1.01)
tgenr	731229 (1.03)	1459572 (1.03)
pigap	721184 (1.01)	1439511 (1.01)
combotglik	687003 (1.05)	1371135 (1.05)
tgdbf	670474 (1.02)	1338069 (1.02)
tgdbftip	667741 (1.00)	1332645 (1.00)
tgdvxtip	666148 (1.00)	1329452 (1.00)
tgdvxpi	644754 (1.03)	1286459 (1.03)
combotgbf	644754 (1.00)	1286459 (1.00)
phivtx	621056 (1.04)	1239008 (1.04)
opsveto	609426 (1.02)	1216002 (1.02)
timkf	543459 (1.12)	1084486 (1.12)
npitg	543459 (1.00)	1084486 (1.00)
kic	543336 (1.00)	1084243 (1.00)
tgzfool	530074 (1.03)	1057691 (1.03)
layv	530069 (1.00)	1057676 (1.00)
tgpvcut	526096 (1.01)	1049965 (1.01)
ccdpul	235592 (2.23)	470537 (2.23)
epionk	234363 (1.01)	468036 (1.01)
ccdbadtim	233082 (1.01)	465416 (1.01)
ccdfib	233082 (1.00)	465415 (1.00)
verrng	214824 (1.08)	428927 (1.09)
angli	214732 (1.00)	428734 (1.00)
allkfit	212394 (1.01)	424112 (1.01)
tpics	212345 (1.00)	424014 (1.00)

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Cuts	1/3 Loose	2/3 Loose
costd	193686 (1.10)	385979 (1.10)
zfrf	167224 (1.16)	333359 (1.16)
zutout	167085 (1.00)	333090 (1.00)
rsdedxmax	120616 (1.39)	240598 (1.38)
rsdedxcl	70050 (1.72)	139105 (1.73)
rslike	67722 (1.03)	134313 (1.04)
rsdedx	67722 (1.00)	134313 (1.00)
utcqual	64701 (1.05)	128191 (1.05)
prrf	38737 (1.67)	76657 (1.67)
prrfz	33215 (1.17)	65601 (1.17)
comboprrf	33215 (1.00)	65601 (1.00)
tggeo	33215 (1.00)	65601 (1.00)
piflg	26295 (1.26)	51902 (1.26)
tgdedx	26062 (1.01)	51437 (1.01)
pvpnnone	**5598** (4.66)	**11039** (4.66)
elveto	2117 (2.64)	4142 (2.67)
tdfool	2090 (1.01)	4104 (1.01)
tdnn	86 (24.30)	166 (24.72)
evfive	86 (1.00)	166 (1.00)
combotd	**86** (1.00)	**166** (1.00)
Total Rej.	65.09 ± 6.97	66.50 ± 5.12

Table 22: Rejection Branch for Muon Background. (not added yet??? Tight has the tight version of PV, DELCO, TD, BOX applied). The numbers represent the number of events remaining after application of the cut designated on a given row. Number in parenthesis is the rejection of the cut.

Cuts	1/3 Loose	2/3 Loose
badrun	12892493 (0.00)	25768044 (0.00)
Tnono	12823737 (1.01)	25631012 (1.01)
DUPEV	12823737 (1.00)	25631012 (1.00)
rdtrk	12823737 (1.00)	25631012 (1.00)
trktim	12823737 (1.00)	25631012 (1.00)
target	12823737 (1.00)	25631012 (1.00)
stlay	12823737 (1.00)	25631012 (1.00)
utc	12823737 (1.00)	25631012 (1.00)
rdutm	12823737 (1.00)	25631012 (1.00)
badstc	12823737 (1.00)	25631012 (1.00)
pdc	12823737 (1.00)	25631012 (1.00)
bfdedx	11409696 (1.12)	22803548 (1.12)
bwtrs	8868972 (1.29)	17724324 (1.29)
bftrs	8220794 (1.08)	16427904 (1.08)
bfetcon	8135020 (1.01)	16256902 (1.01)
bfccd	8036604 (1.01)	16060975 (1.01)
cpitrs	7688327 (1.05)	15362723 (1.05)
cpitail	7684992 (1.00)	15355998 (1.00)
cktrs	5335463 (1.44)	10660536 (1.44)
cktail	5062839 (1.05)	10118608 (1.05)
tgqualt	4815371 (1.05)	9625818 (1.05)
timcon	4789227 (1.01)	9573254 (1.01)
tgtcon	4683555 (1.02)	9361755 (1.02)
rvtrs	4666832 (1.00)	9328367 (1.00)
upvtrs	4585317 (1.02)	9165183 (1.02)
delco	3976305 (1.15)	7947312 (1.15)
tggeo	2926088 (1.36)	5848653 (1.36)
combops	2926088 (1.00)	5848653 (1.00)
$\overline{TD_{loose}}$	2115217 (1.38)	4226709 (1.38)
box	64304 (32.89)	128749 (32.83)
bfekz	51345 (1.25)	103503 (1.24)
epitg	42559 (1.21)	86159 (1.20)
epimaxk	42559 (1.00)	86159 (1.00)
targf	39886 (1.07)	80451 (1.07)
tger	39838 (1.00)	80308 (1.00)
dtgttp	39836 (1.00)	80308 (1.00)
rtdif	39505 (1.01)	79653 (1.01)
drp	39196 (1.01)	79051 (1.01)
tgktim	38772 (1.01)	78223 (1.01)
eiccon	37943 (1.02)	76624 (1.02)
ticcon	37943 (1.00)	76624 (1.00)
tgedge	37532 (1.01)	75741 (1.01)
tgenr	36831 (1.02)	74276 (1.02)
pigap	36487 (1.01)	73624 (1.01)
combotglik	33959 (1.07)	68304 (1.08)
tgdbf	33040 (1.03)	66489 (1.03)
tgdbftip	32650 (1.01)	65664 (1.01)
tgdvxtip	32455 (1.01)	65316 (1.01)
tgdvxpi	32001 (1.01)	64341 (1.02)

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Cuts	1/3 Loose	2/3 Loose
$combotgbf$	32001 (1.00)	64341 (1.00)
$phivtx$	29934 (1.07)	60077 (1.07)
$opsveto$	28194 (1.06)	56624 (1.06)
$timkf$	24895 (1.13)	50209 (1.13)
$npitg$	24895 (1.00)	50209 (1.00)
kic	24889 (1.00)	50199 (1.00)
$tgzfool$	24447 (1.02)	49365 (1.02)
$layv$	24447 (1.00)	49365 (1.00)
$tgpvcut$	23721 (1.03)	47882 (1.03)
$rngmom$	1728 (13.73)	3513 (13.63)
$costd$	1667 (1.04)	3375 (1.04)
$zfrf$	1665 (1.00)	3363 (1.00)
$zutout$	1656 (1.01)	3333 (1.01)
$rsdedxmax$	1463 (1.13)	2930 (1.14)
$rsdedxcl$	1303 (1.12)	2627 (1.12)
$rslike$	1303 (1.00)	2627 (1.00)
$rsdedx$	1303 (1.00)	2627 (1.00)
$utcqual$	1173 (1.11)	2410 (1.09)
$prrf$	1160 (1.01)	2378 (1.01)
$prrfz$	1063 (1.09)	2184 (1.09)
$comboprrf$	1063 (1.00)	2184 (1.00)
$tggeo$	1063 (1.00)	2184 (1.00)
$piflg$	1028 (1.03)	2114 (1.03)
$tgdedx$	1006 (1.02)	2062 (1.03)
$ccdpul$	187 (5.38)	364 (5.66)
$epionk$	185 (1.01)	362 (1.01)
$ccdbadtim$	179 (1.03)	353 (1.03)
$ccdfib$	179 (1.00)	353 (1.00)
$verrng$	134 (1.34)	258 (1.37)
$angli$	134 (1.00)	257 (1.00)
$allkfit$	130 (1.03)	249 (1.03)
$tpics$	130 (1.00)	249 (1.00)
$tgdedx$	130 (1.00)	249 (1.00)
$chifss$	105 (1.24)	210 (1.19)
$chifmax$	105 (1.00)	210 (1.00)
PV_{pnn2}	**0** (105.00)	**1** (210.00)

Table 23: Normalization Branch for Muon Background. (not added yet??? Tight has the tight version of PV, DELCO, BOX applied). The numbers represent the number of events remaining after application of the cut designated on a given row. Number in parenthesis is the rejection of the cut.

After some setup cuts that remove $K_{\pi 2}$ decays and beam backgrounds, in the normalization branch (Table 23) the loose TDCUT02 is inverted for both the loose and tight regions; this is done to prevent us from looking in the box. When the remaining cuts are applied (KCUTS and PVPNN2), zero events remains in the normalization branch, as shown in Table 23, therefore N=1 will be used for the background estimation. In the rejection branch, RNGMOM is inverted and the rejection of the TDCUT02 is measured on this sample. Using these values, the muon background is

$$\begin{aligned} N_{muon_{\frac{1}{3}loose}} &= 3 \times \frac{N_{loose}}{R_{TD_{loose}} - 1} && (18) \\ &= 3 \times \frac{1 \pm 1}{(65.09 \pm 6.97) - 1} \\ &= 0.0468 \pm 0.0468 && (19) \end{aligned}$$

$$\begin{aligned} N_{muon_{\frac{2}{3}loose}} &= \frac{3}{2} \times \frac{N_{loose}}{R_{TD_{loose}} - 1} && (20) \\ &= \frac{3}{2} \times \frac{1 \pm 1}{(66.50 \pm 5.12) - 1} \\ &= 0.0229 \pm 0.0229 && (21) \end{aligned}$$

$$
\begin{aligned}
N^{scale}_{muon_{tight}} &= \frac{A_{PV_{tight}}}{A_{PV_{loose}}} \times \frac{A_{BOX_{tight}}}{A_{BOX_{loose}}} \times \frac{A_{BOX_{tight}}}{A_{BOX_{loose}}} \times N_{muon_{loose}} \qquad (22) \\
&= \frac{0.356}{0.639} \times \frac{0.704}{0.942} \times (0.68) \times \frac{0.704}{0.857} \times 0.0229 \pm 0.0229 \\
&= 0.0053 \pm 0.0053 \qquad (23)
\end{aligned}
$$

7 Charge exchange background

8 K_{e4} background

9 Background Contamination Studies

Text of Joss's studies of background contamination should go in this section.

10 Acceptance

Needs to be updated for 2/3 analysis.

11 Kaon exposure

Taken directly from 1/3 note. Has it changed?

The total KB_{Live} was measured to be 1.7096×10^{12}. This took into account runs which were removed after E949-PNN1 analysis, see [8]. This also included all runs listed in `$PASS2_ANAL/func/ bad_run_02.function` which include runs removed by Joss due to bad cktbm data and bad target ccd data.

12 Single Cut Failure Study

Needs to be written for 2/3 analysis.

13 Sensitivity

Needs to be written for 2/3 analysis.

	Tight cuts	Loose cuts
skim123	25768044	25768044
delco2	15743575	15743575
KCUTS	423053	592084
CKTRS	374726(0.885)	524435(0.885)
CKTAIL	366054(0.976)	512270(0.976)
CPITRS	259740(0.709)	382042(0.745)
CPITAIL	259442(0.998)	381643(0.998)
BWTRS	245502(0.946)	362127(0.948)
B4DEDX	242944(0.989)	358323(0.989)
B4TRS	224029(0.922)	330320(0.921)
B4CCD	220373(0.983)	325020(0.983)
TIMCON	218457(0.991)	321662(0.989)
IPIFLG	217349(0.994)	320044(0.994)
ELVETO	202144(0.930)	298045(0.931)
TDFOOL	201803(0.998)	297521(0.998)
TDVARNN	137530(0.681)	273819(0.920)
PVCUT	426(0.003)	2938(0.010)
KPIGAP	15(0.035)	98(0.033)
TGZFOOL	13(0.866)	79(0.806)
EPITG	5(0.384)	55(0.696)
EPIMAXK	5(1.000)	55(1.000)
EPIONK	5(1.000)	55(1.000)
TIMKF	3(0.600)	39(0.709)
KIC	2(0.666)	30(0.769)
TGQUALT	2(1.000)	30(1.000)
NPITG	2(1.000)	30(1.000)
TGER	2(1.000)	29(0.966)
DTGTTP	2(1.000)	29(1.000)
RTDIF	2(1.000)	29(1.000)
DRP	2(1.000)	29(1.000)
TGKTIM	2(1.000)	28(0.965)
TGEDGE	2(1.000)	27(0.964)
TGDEDX	2(1.000)	25(0.925)
TGENR	2(1.000)	23(0.920)
PIGAP	2(1.000)	22(0.956)
TGLIKE	2(1.000)	16(0.727)
TGB4	0(0.000)	7(0.437)
PHIVTX	0( )	7(1.000)
TPICS	0( )	7(1.000)
TGTCON	0( )	7(1.000)
B4ETCON	0( )	7(1.000)
TGGEO	0( )	0(0.000)

Table 24: The pass2 cuts history of the normalization branch of the 2/3 data for the CEX study.

	Tight cuts	Loose cuts
N_{norm}	1	1
$N_{targf,\ UMC}$	6^{+6}_{-2}	50^{+33}_{-10}
$N_{kpigap,\ UMC}$	3332	4136
N_{CEX}	$0.0023 \pm 0.0023^{+0.0023}_{-0.0008}$	$0.015 \pm 0.015^{+0.012}_{-0.003}$

Table 25: CEX background number normalized to 3/3 data. The first error of N_{CEX} is statistical and the second error is the estimated systematic uncertainty due to TGPV, OPSVETO and CCDPUL.

	Loose cuts	Tight cuts
skim123	25768044	25768044
KCUTS	1530745	1131416
PCUTS	360123	242199
TDCUTS	306179	152260
PVCUT	6048	1020
DELC	3350(0.553)	554(0.543)
DELC3	3340(0.997)	481(0.868)
TGZFOOL	3215(0.962)	463(0.962)
R-cut	3142(0.977)	446(0.963)
PVICVC	2343(0.745)	311(0.697)
B4EKZ	1853(0.790)	254(0.816)
EPITG	1080(0.582)	131(0.515)
EPIMAXK	1080(1.000)	131(1.000)
TIMKF	816(0.755)	103(0.786)
KIC	804(0.985)	102(0.990)
TGQUALT	714(0.888)	94(0.921)
NPITG	714(1.000)	94(1.000)
TGER	712(0.997)	94(1.000)
TARGF	669(0.939)	85(0.904)
DTGTTP	669(1.000)	85(1.000)
RTDIF	661(0.988)	85(1.000)
DRP	598(0.904)	80(0.941)
TGKTIM	592(0.989)	80(1.000)
TGEDGE	558(0.942)	79(0.987)
TGDEDX	506(0.906)	64(0.810)
TGENR	499(0.986)	63(0.984)
PIGAP	491(0.983)	62(0.984)
TGLIKE	446(0.908)	57(0.919)
TGB4	433(0.970)	55(0.964)
PHIVTX	187(0.431)	25(0.454)
CHI567	155(0.828)	15(0.600)
CHI5MAX	155(1.000)	15(1.000)
VERRNG	137(0.883)	14(0.933)
ANGLI	137(1.000)	14(1.000)
TGFITALLK	130(0.948)	14(1.000)
TPICS	130(1.000)	14(1.000)
TGTCON	130(1.000)	14(1.000)
B4ETCON	129(0.992)	14(1.000)
CCDBADTIM	125(0.968)	14(1.000)
CCDBADFIT	112(0.896)	14(1.000)
CCD31FIB	112(1.000)	14(1.000)
CCDPUL	6(0.053)	0(0.000)
EPIONK	6(1.000)	0( )

Table 26: The pass2 cuts history of the normalization branch of the 2/3 data for K_{e4} study. R-cut is $\overline{\mathrm{TGPV} \cdot \mathrm{OPSVETO}}$.

	$T_{xtg} < 0.6$	$T_{xtg} < 1.2$	$T_{xtg} < 1.8$
$E_{hide} < 1.6$	$2250/66 = 34$	$2250/86 = 26$	$2250/98 = 23$
$E_{hide} < 2.5$	$6769/100 = 68$	$6769/129 = 52$	$6769/149 = 45$
$E_{hide} < 4.0$	$34992/202 = 173$	$34992/288 = 122$	$34992/335 = 104$
$E_{hide} < 10.0$	$97100/627 = 155$	$97100/888 = 109$	$97100/1105 = 88$

Table 27: Rejection of $R_{TGPV \cdot OPSVETO}$ as a function of E_{hide} for loose cuts.

	$T_{xtg} < 0.6$	$T_{xtg} < 1.2$	$T_{xtg} < 1.8$
$E_{hide} < 1.6$	$389/18 = 22$	$389/20 = 19$	$389/22 = 18$
$E_{hide} < 2.5$	$2282/23 = 99$	$2282/26 = 88$	$2282/31 = 74$
$E_{hide} < 4.0$	$15105/43 = 351$	$15105/53 = 285$	$15105/65 = 232$
$E_{hide} < 10.0$	$37174/160 = 232$	$37174/206 = 180$	$37174/269 = 138$

Table 28: Rejection of $R_{TGPV \cdot OPSVETO}$ as a function of E_{hide} for tight cuts.

	Loose cuts	Tight cuts
N_{norm}	6	1
$R_{TGPV \cdot OPSVETO}$	52^{+121}_{-29}	88^{+263}_{-70}
$N_{K_{e4}}$	$0.176 \pm 0.072^{+0.233}_{-0.124}$	$0.017 \pm 0.017^{+0.071}_{-0.013}$

Table 29: K_{e4} background number normalized to 3/3 data. The first error of $N_{K_{e4}}$ is statistical and the second error is from $R_{TGPV \cdot OPSVETO}$.

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